國立交通大學

網路工程研究所

碩 士 論 文

都會區車輛隨意網路之多重路徑繞徑技術

Road-Based Multipath Routing in Urban VANETs

研 究 生：鍾昆佑

指導教授：王國禎 博士

中 華 民 國 101 年 6 月

都會區車輛隨意網路之多重路徑繞徑技術

Road-Based Multipath Routing in Urban VANETs

研 究 生：鍾昆佑　　　Student: Kun-Yu Chung

指導教授：王國禎　　　Advisor: Kuochen Wang

國 立 交 通 大 學
資 訊 學 院
網 路 工 程 研 究 所

碩 士 論 文

A Thesis

Submitted to Institute of Network Engineering

College of Computer Science

National Chiao Tung University

in Partial Fulfillment of the Requirements

for the Degree of

Master

In

Computer Sciencmae

June 2012

Hsinchu, Taiwan, Republic of China

中華民國101年6月

都會區車輛隨意網路之多重路徑繞徑技術

學生：鍾昆佑　　　指導教授：王國禎 博士

國立交通大學 資訊學院 網路工程研究所

摘 要

在車載隨意網路(VANETs)裡，節點(車輛)的高移動性而造成封包的遺失是一個很常見的問題，很多文獻嘗試去解決這個問題。CLA為基於道路之單一路徑繞徑技術協定，一旦路徑斷裂，它必須要再建立一條新的路徑。AOMDV和NDMR為多重路徑繞徑技術協定，若是一條路徑斷裂，它們會選擇另一條路徑。但是AOMDV和NDMR是基於節點來建立路徑的繞境技術協定，它們的路徑比基於道路繞徑技術協定建立的路徑還要容易斷裂。在本論文中，我們提出了一個基於路段之多重路徑繞徑技術(RBMR)協定。就我們所知，在現有文獻中還沒有基於路段之多重繞徑技術協定。我們嘗試從寄送者到接收者之間建立兩條最快的路徑。為了減少路徑斷裂的影響，我們利用即時的交通資訊，如位在傳輸範圍內的車輛識別碼，來建立並維持兩條基於路段且節點不共用的路徑。一旦一條路徑(第一條路徑)被建立好後，這條路徑會立即用來傳送封包。當第一條路徑斷裂後，下一條被建立的好路徑(第二條路徑)將會被使用。以即時的交通資訊為基礎，我們提出的RBMR，在每一

段路段內，藉由車輛存在績分(VPS)的參數來選擇相對穩定的中繼點來傳送封包，以使封包傳輸更穩定。模擬結果顯示，我們提出的RBMR和AOMDV，NDMR和CLA相比較，分別提升了封包傳輸率9%、6%及15%，減少點對點的延遲時間28%、11%及7%，以及減少了額外控制負荷30%、25%及19%。

關鍵詞：基於路段、多重路徑繞徑、基礎節點不共用、都會區車載隨意網路。

Road-based Multipath Routing in Urban VANETs

Student: Kun-Yu Chung　　Advisor: Dr. Kuochen Wang

Department of Computer Science
National Chiao Tung University

Abstract

In vehicular ad-hoc networks (VANETs), packet loss is a common problem because of high node (vehicle) mobility. Many literatures tried to solve this problem. Connectionless approach (CLA) is a road-based single path routing protocol. If a route disconnects, it has to create a new route. Ad-hoc on-demand multipath distance vector (AOMDV) and node-disjoint multipath routing (NDMR) are multipath routing protocols. They can switch to another route if ones route is disconnected. However, since AOMDV and NDMR are node-centric routing protocols, a route is easier to be disconnected than that in road-based routing protocols. In this paper, we propose a novel road-based multipath routing (RBMR) protocol. To the best of our knowledge, there is no existing road-based multipath routing protocol. In the proposed RBMR, it attempts to establish two fast routes from sender to receiver. It uses real-time vehicular traffic information, such as the IDs of vehicles within the radio transmission range, to create and maintain two road-based node-disjoint routes to reduce the impact of broken links. Once a route (the first route) is first established, it will be used to send packets immediately. The next established route (the second route) will be used if the first route is disconnected. Based on real-time vehicular traffic, the proposed RBMR selects a relatively stable node as a relay node in a road segment based on the vehicle persistence score (VPS) for data forwarding. Simulation results show that the proposed RBMR improves the packet delivery ratio by 9%, 6%, and 15%, end-to-end delay by 28%, 11%, and 7%, and control overhead by 30%, 25%, and 19% compared with AOMDV, NDMR, and CLA, respectively.

Keywords: Road-based, multipath routing, node-disjoint, urban VANETs.

Acknowledgements

Many people have helped me with this thesis. I deeply appreciate my thesis advisor, Dr. Kuochen Wang, for his intensive advice and guidance. I would like to thank all the members of the Mobile Computing and Broadband Networking Laboratory (MBL) for their invaluable assistance and suggestions. The supports by National Science Council under Grants NSC 99-2221-E-009-081-MY3, NSC 100-2219-E-009-004 and NSC 101-2219-E-009-001 are gratefully acknowledged.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

Without base stations and infrastructures, a vehicular ad-hoc network (VANET) is an instantly deployable wireless network [1]. It consists of mobile nodes (vehicles). Each node moves arbitrarily and communicates with others by wireless links [2]. So the topology of the VANET changes frequently.

The routing protocols can be categorized into proactive routing protocols and reactive routing protocols [3]. The traditional proactive and reactive routing protocols were designed for mobile ad hoc networks (MANETs) routing protocols that their packet delivery ratios are poor if they are applied to VANETs directly [4]. They establish node-centric view of routes (i.e., a route is established between source and destination in advance) that may break frequently because of VANETs' high mobility. This is called the node-centric problem, as illustrated in Figure 1 [4].

(a) At time *t* (b) At time *t + a*

Figure 1. Node-centric problem.

In Figure 1(a), S is the source node and D is the destination node. When S wants to send packets to D at time *t* and N2 is a relay node. So the route from S to D is from S to N2 to D. After time *a*, N2 is out of the transmission range of S, so the route from S to D is broken. If S wants to send packets to D, it has to find another new route, and it will result in control overhead and transmission delays [4].

In order to resolve the above problem, greedy perimeter stateless routing (GPSR) [5] was proposed. It chooses the node which is in the transmission range of the sender and is the closest neighbor to the destination. So in Figure 1(b) S will choose N1 instead of N2. Since there are dead end roads in urban VANETs, GPSR do not always perform well in urban VANETs [4]. For instance, in Figure 2, S is the source and D is the destination. And N1 and N2 are in the transmission range of S. When S is ready to send packets to D, it will choose N2 as a relay node in GPSR. And N3 will be chosen by N2. But the road which N3 is locates is a dead end. So N3 has no node to choose as a relay node [4]. This is called the *geographical routing* problem.

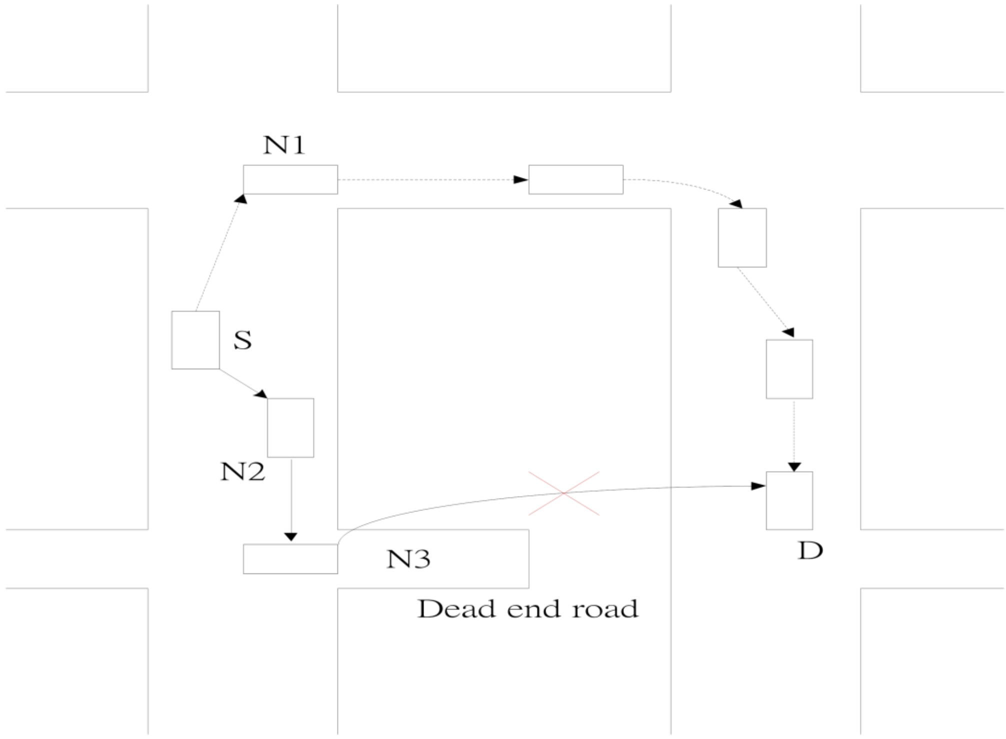

Figure 2. Geographical routing problem [4].

To resolve the node-centric problem and the geographical routing problem, road-based routing was proposed. RBVT [4] is a road-based routing protocol that leverages real-time vehicular traffic information to create paths. It records road segment IDs instead of node IDs. In Figure 1, S will record the road segment ID, A1, instead of the node ID, N2. If S wants to send packets to D, it will choose the node which is on A1 and in the transmission range of S. So in Figure 1(b), N1 will be chosen as a relay node instead of N2. But RBVT creates only one path; if the only path breaks, it has to create a new path.

Multipath routing creates several routes from sender to receiver. So if one route is disconnected, the sender can choose another route for packet transmission. So multipath routing can reduce control overhead and increase packet delivery ratio [6]. In this paper, we propose a *road-based multipath routing* (RBMR) protocol, which focuses on establishing two routes from sender to receiver. To the best of our knowledge, there is no existing road-based multipath routing protocol. The proposed RBMR uses real-time vehicular traffic information to create two road-based node-disjoint routes. The RBMR begins to send packets once a route is first established. The route (the second route) next established later will be used if the first route is disconnected.

The rest of this paper is organized as follows. Related work is reviewed in Chapter 2. In Chapter 3, we describe the background of vehicle persistence score. In Chapter 4, we detail the proposed RBMR. Simulation results are shown in Chapter 5. In Chapter 6, we give concluding remarks and outline future work.

Chapter 2

Related Work

Connectionless approach (CLA) [7] is a road-based single path routing protocol. It records road segment IDs instead of node IDs. If a route disconnects, it has to create a new route. Multipath routing can improve the packet delivery ratio compared with single path routing, which has been proved in [6]. Multipath routing protocols can be classified into *node-disjoint routing* and *link-disjoint routing* [8]. Paths which are called node-disjoint mean they have no common node besides source and destination nodes. And paths which are called link-disjoint mean they have no common link. Figure 3 shows two node-disjoint paths. There are two paths from source S to destination D; one is S-A-B-D and the other is S-M-N-D. There are no common node except S and D. Figure 4 shows two link-disjoint paths. S-A-B-C-D and S-M-B-N-D are two paths from source S and destination D. Because B is a common node, so the two paths are not node-disjoint. But the two paths have no common link, so they are called link-disjoint. The node-disjoint routes have been proved to have better performance than the link-disjoint routes on breaking probability of paths [9].

Ad-hoc on-demand multipath distance vector routing (AOMDV) [10], which is a node-centric and link-disjoint protocol, creates several paths from source to destination, and packets are sent after paths established. So it wastes time for establishing several paths before packets can be transmitted. Node-disjoint multipath routing (NDMR) [11] is a node-disjoint multipath routing protocol. It sends packets right away after creating one path, but it is a node-centric routing protocol. Therefore, the path is easy to be disconnected in the NDMR than that in a road-based routing protocol. Table 1 is a qualitative comparison of existing VANET routing protocols CLA, AOMDV, NDMR, and the proposed RBMR.

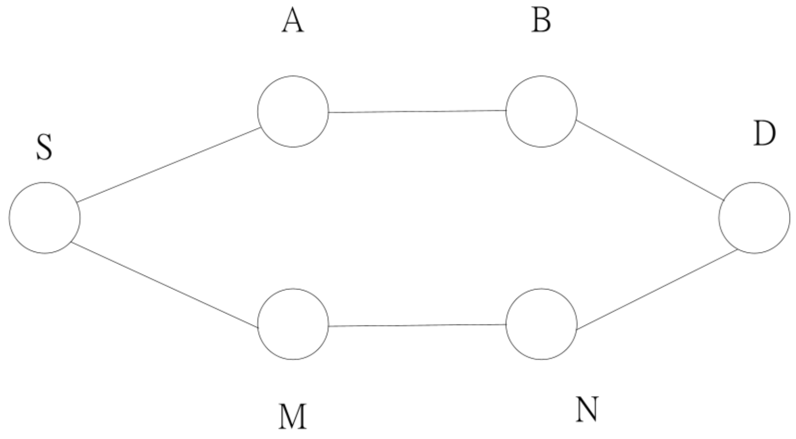

Figure 3. Two node-disjoint paths.

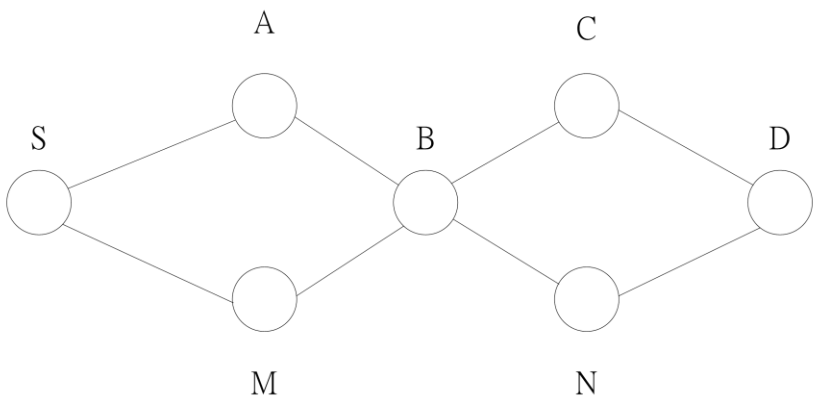

Figure 4. Two link-disjoint paths.

Table 1. A qualitative comparison of existing VANET routing protocols, including the proposed RBMR.

Routing protocol	CLA [7]	AOMDV [10]	NDMR [11]	RBMR(proposed)
Path count	1	≧2	2	2
Node-centric or Road-based	Road-based	Node-centric	Node-centric	Road-based
Node-disjoint or Link-disjoint	- (Single path routing)	Link-disjoint	Node-disjoint	Node-disjoint
Obstacles considered	Yes	No	No	Yes

Chapter 3

Background

A reliable routing scheme based on vehicle moving similarity (RR-VMS) was proposed in [12]. This routing scheme selects a relay node by using a vehicle persistence score (VPS). A node's neighbor which has a higher VPS means it has stayed long with the node. In order to select a stable neighbor, neighbors' information within the transmission range has to be updated periodically. So a node sends a HELLO message to its 1-hop neighbors of the node regularly. Each node has a VPS table to record neighbors' information. After receiving a HELLO message, a node will update its VPS table. A column, *position,* is added to the original HELLO message in [12]. Position is a global position system (GPS) coordinate (x, y) of a node. We use the GPS coordinate of a neighbor to calculate the neighbor's direction. If the distance between the neighbor and the destination becomes smaller, it means the neighbor moving towards the destination. A relay node is chosen by the VPS value. An entry of the VPS table is < *neighbor ID, position, road segment ID, direction, VPS* >, which are defined as follows [13]:

Neighbor ID: the neighbor's identifier.

Position: the GPS coordinate (x, y), which stands for the neighbor's position.

Road segment ID: where the neighbor is located.

Direction: whether the neighbor's moving direction towards the receiver.

VPS: the value is used to reflect the neighbor's stability.

When a node gets a HELLO message from a neighbor, it searches the VPS table. If the neighbor's ID does not exist in the node's VPS table, the node adds the related information in the entry of the neighbor's ID in the VPS table. And the VPS will be assigned to 1. If the neighbor's ID exists in the VPS table, the VPS of this neighbor ID will be increased by 1 [13].

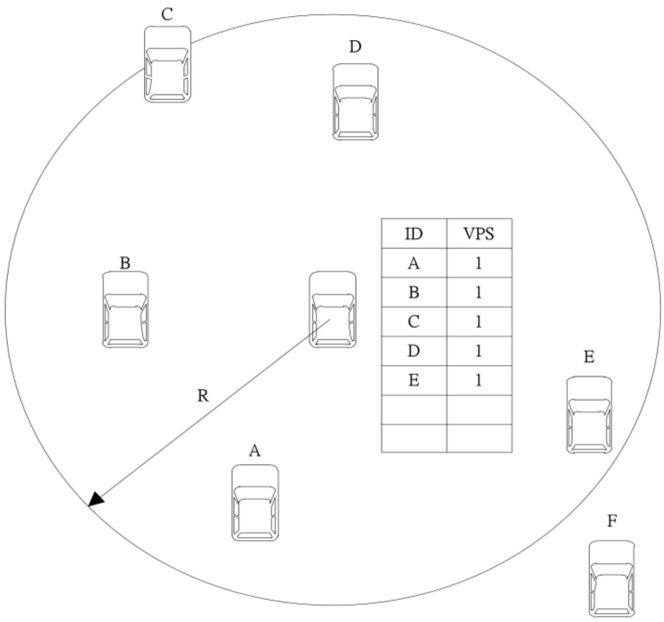

Figure 5. VPS values are initialized when receiving a HELLO message for the first time.

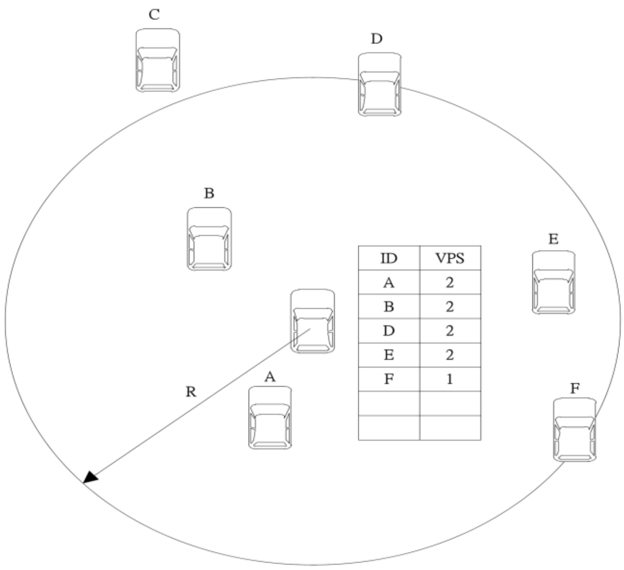

Figure 6. VPS values are incremented when receiving another HELLO message.

Figures 5 and 6 show how to update VPS values. The VPS table belongs to node Z. The circle is the radio transmission range of Z. In Figure 5, because nodes A、B、C、D and E are in the transmission range of Z, so their node IDs and VPS values can be found in the table. However, F is not in the transmission of Z, so it is not shown in the table. After receiving another HELLO message, in Figure 6, because A、B、D and E are still in the transmission of Z, so their VPS values are increased by 1. But C is out of the circle (radio transmission range), so its record is deleted from the table. Now F is inside the circle for the first time, so its VPS is assigned to 1.

Chapter 4

Proposed Road-Based Multipath Routing (RBMR) Protocol

The main objective of the proposed RBMR protocol is to establish and maintain two node-disjoint paths and begin packet transmission once the first route (path) is established. The second route is a backup route. This protocol can be divided two stages: *route discovery stage* and *packet transmission stage*.

4.1 Route discovery stage

Figure 7 shows a neighbor node handling a received RREQ. A sender will first send an RREQ packet to neighbors when it wants to send data packets to a receiver. The RREQ's header includes sender ID, receiver ID, and a unique RREQ ID. If a neighbor node gets the RREQ with the same sender ID and RREQ ID with a previously received RREQ, it discards this RREQ. When a neighbor receives a new RREQ, it checks if it is located on a different road segment ID from that of the sender in the RREQ. If yes, the neighbor node adds the road segment ID to the RREQ header and broadcasts the RREQ [4].

When the receiver gets the RREQ, it checks whether there is any road segment ID the same as a road segment ID except sender ID and receiver ID in a previously received RREQ. If yes, the receiver discards this RREQ. If no, the receiver sends an RREP, that include its GPS coordinates (x, y), back to the sender through a path that follows the reverse order of road segment IDs in the header. And each node on the path will recorded the receiver's GPS coordinates. If the sender gets an RREP, the sender proceeds to the packet transmission stage immediately instead of waiting for the second RREP. The second RREP is used to establish the second route that will be used if the first route is disconnected.

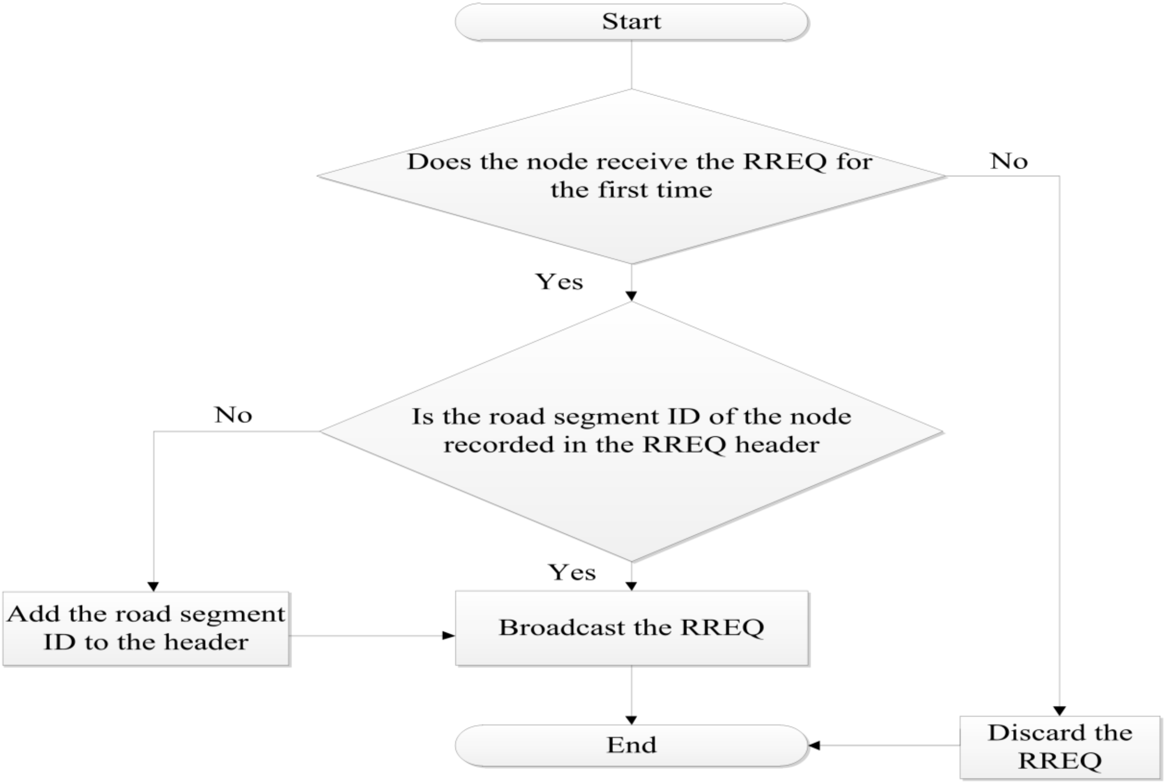

Figure 7. How a neighbor node handles a received RREQ.

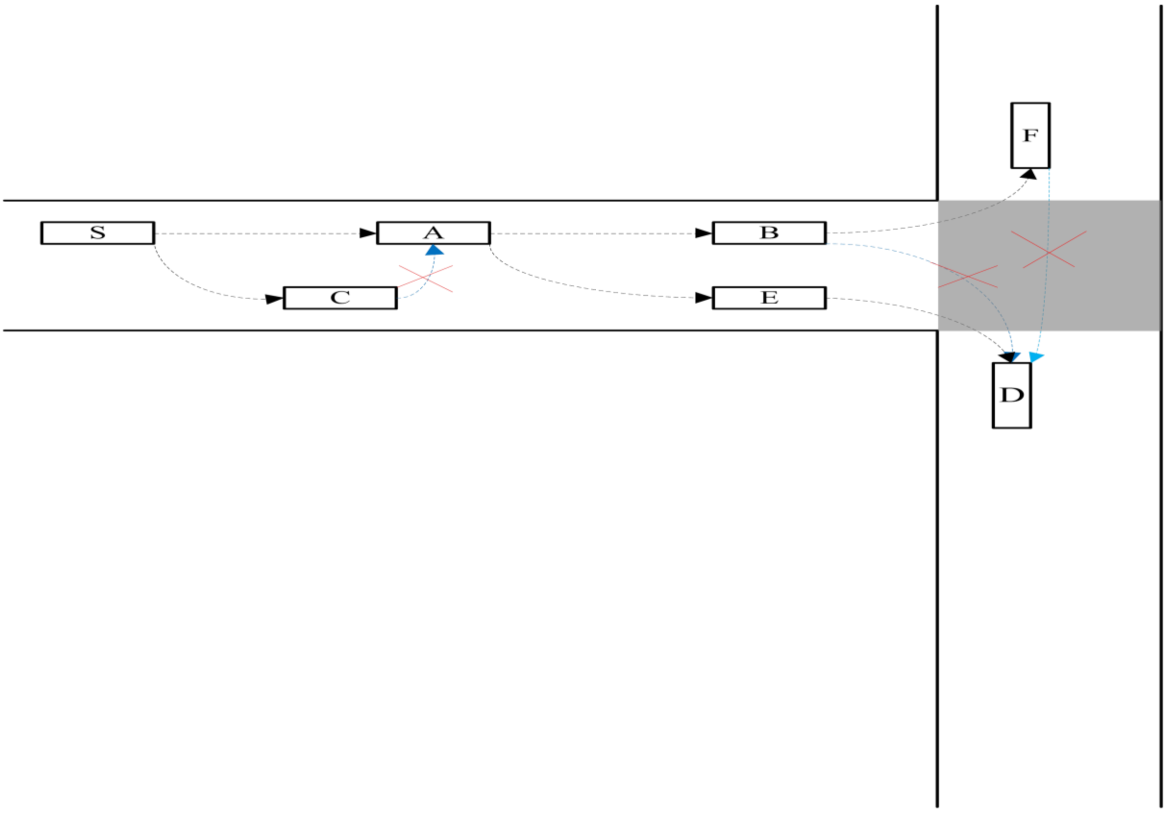

Figure 8. How RREQ packets being forwarded.

Figure 8 shows how RREQ packets being forwarded. We split up Figure 8 to eight steps. In step 1, sender S sends an RREQ to nodes A and C. In step 2, node C sends an RREQ to node A. In step 3, node A discards the RREQ which is received from node C because it has received the same RREQ from sender S. In step 4, node A sends the RREQ to node B and E. In step 5, node E sends the RREQ to node D. In step 6, node B sends the RREQ to nodes F and D. In step 7, node D discards the RREQ which is received from node B because node D has received the same RREQ from node E. In step 8, node F sends the RREQ to receiver D, but receiver D discards this RREQ because it has received the same RREQ from node E before.

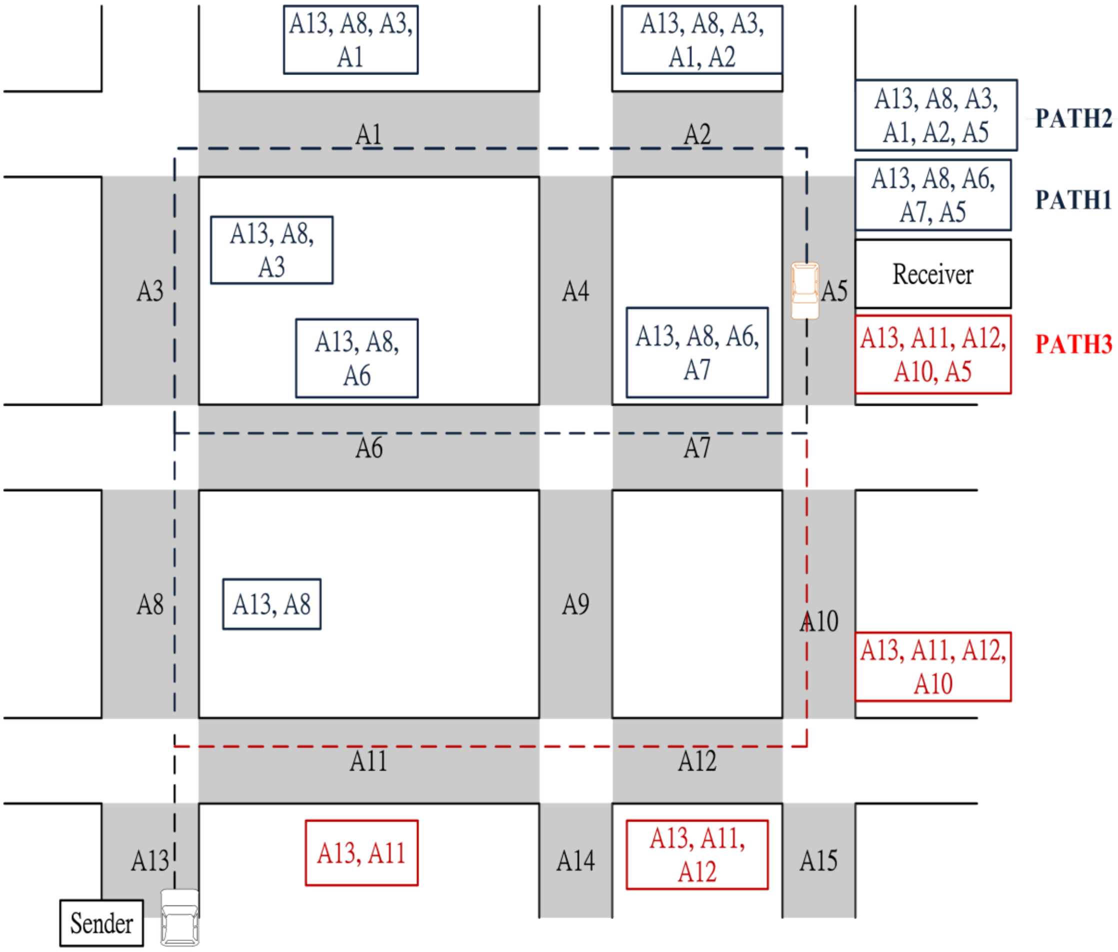

Figure 9. Road segment IDs recorded in the RREQ header.

In Figure 9, we show how the proposed RBMR creating two paths from a sender to a receiver. When the receiver gets RREQ, it checks whether the road segment IDs are the same as previous road segment IDs. If the road segment IDs are the same, it discards it. If the road segment IDs are not the same except the sender's and the receiver's, it sends RREP back to the sender which follows the reverse road segment IDs order in the header. In Figure 9, the receiver gets PATH1, PATH2, and PATH3. The receiver discards PATH2 because A8 is used in PATH1**.** In Figure 10, the receiver sends two RREP packets back to the sender by PATH1 and PATH3, respectively, which follows the reverse road segment IDs in the header.

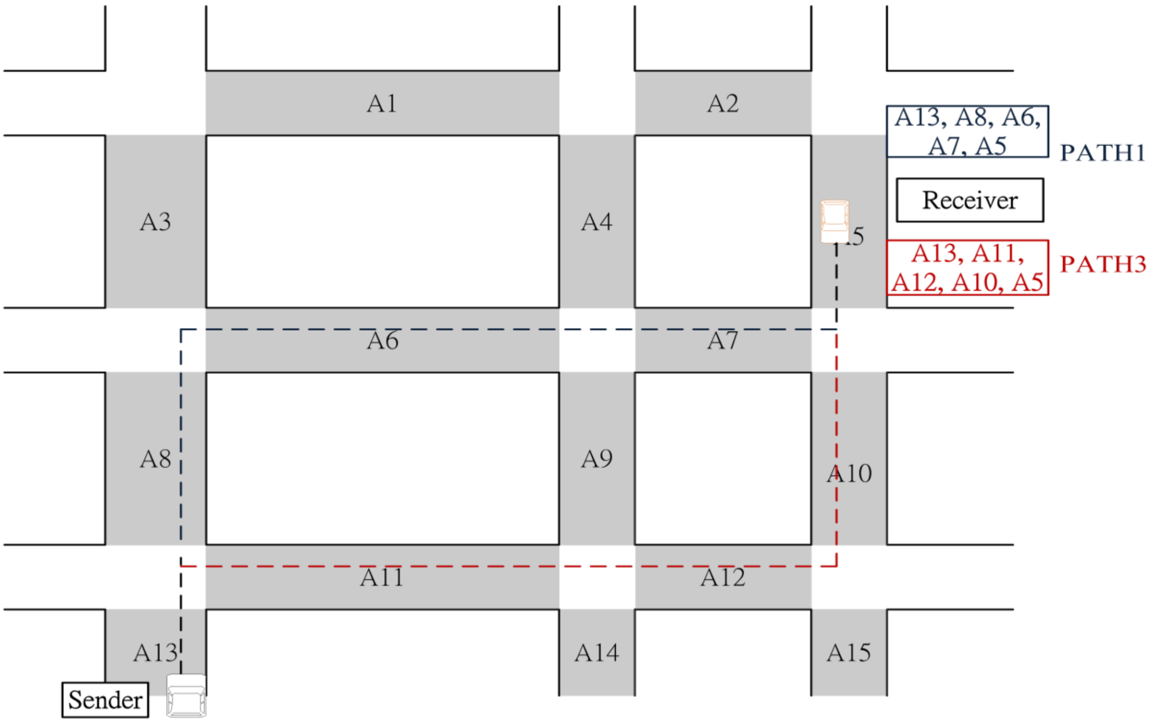

Figure 10. Two RREP packets returned, that include PATH1 and PATH3, respectively, through the reverse road segment IDs order.

4.2 Data forwarding stage

The most important thing in the data forwarding stage is how to select relay nodes along the selected path for data forwarding. The proposed RBMR creates two road-based node-disjoint routes after the route discovery stage. The RBMR begins to send packets once a route is first established. The next route established later will be used if the first route is disconnected. When a sender wants to send packets to a receiver and one route has been established, the next stage is to choose a relay node.

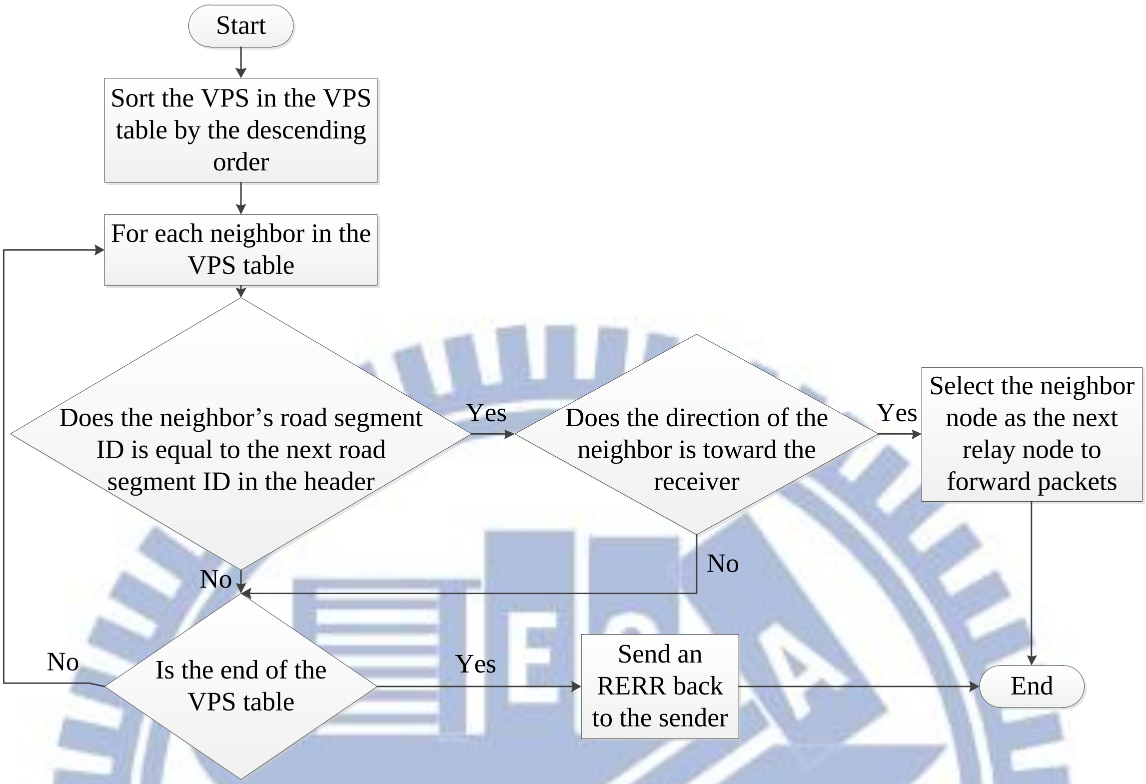

Figure 11 shows how to select a next relay node to forward packets. The procedure of choosing a relay node can be split into three steps. First, it sorts the VPS in the VPS table by the descending order. Second, it checks each neighbor in the VPS table to see whether the next road segment ID in the header is equal to the neighbor’s road segment ID. If yes, it goes to the third step. The third step is used to check whether the direction of the neighbor is toward the receiver. If yes, the sender can send packets to the neighbor, which is a relay node. Then, the relay node will follow the above three steps to select the next relay node to forward packets until the receiver is reached.

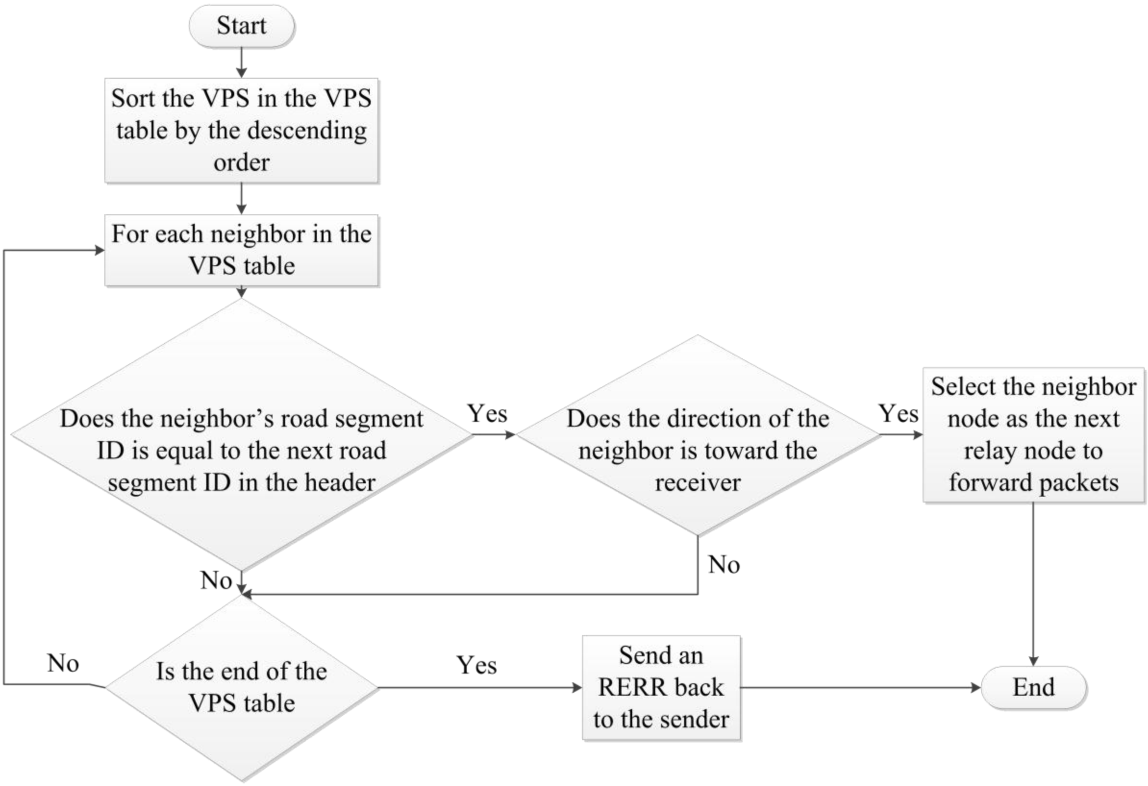

Figure 11. How to select a next relay node to forward packets.

Chapter 5

Evaluation and Discussion

In this chapter, we describe simulation setup and evaluate simulate results. Then, we compare the proposed RBMR with AOMDV [10], NDMR [11], and CLA [7].

5.1 Simulation setup

We use a urban VANET scenario to evaluate the proposed RBMR. Simulations were performed using NS2.34 [13]. Simulation results were acquired by the average of twenty runs. We compare the proposed RBMR with the above three protocols, in terms of packet delivery ratio, end-to-end delay, and control overhead, which are defined as follows:

Packet delivery ratio: the number of data packets received at the receiver divided by the number of data packets generated at the sender [12].

End-to-end delay: the time taken for a data packet to be transmitted (including route acquisition delay) from sender to receiver [7].

Control overhead: when transferring a data packet, how many control packets need to send [12].

Table 2. NS2 simulation settings [6][13].

Parameter	**Value**
Network area	1000 *m* * 1000 *m*
MAC Protocol	IEEE 802.11 *p*
Transmission range	376 *m*
Simulation time	600 *s*
Connection type	CBR
Packet size	512 bytes
Mobility model	VanetMobiSim
Packet sending rate	10 packet/sec
Sender-receiver pairs	10

Table 3. VanetMobiSim parameters for road layout [15].

Parameter	Value
Max traffic lights	10
Terrain size	1000 *m* * 1000 *m*
Min. Speed	8 *m/s (28 km/hr)*
Max. Speed	17 *m/s (61 km/hr)*
Number of nodes	30, 40, 50, 60, 70
Max. acceleration	0.6 m/s
Normal deceleration	0.5 m/s

VanetMobiSim [15] mobility model was used to generating vehicle mobility traces. NS2 and VanetMobiSim parameters for road layout simulation settings are summarized in Table 2 and Table 3, respectively. Note that the radio transmission range was set to 376 *m*, which conforms to the IEEE 802.11p that is an approved amendment to the IEEE 802.11 standard to add wireless access in vehicular environments (WAVE) [16].

5.2 Simulation results and discussion

In Figures 12, 13, and 14 we compare the proposed RBMR with AOMDV, NDMR, and CLA. Simulation results show that the proposed RBMR improves packet delivery ratio by 9%, 6%, and 15%, end-to-end delay by 28%, 11%, and 7%, and control overhead by 30%, 25%, and 19% compared with AOMDV, NDMR, and CLA, respectively.

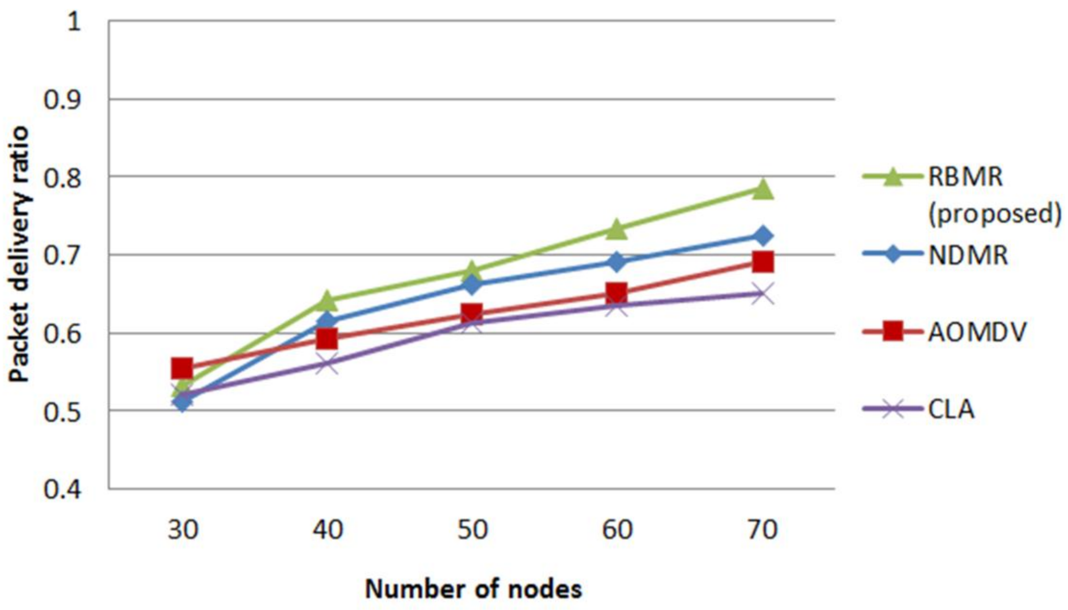

Figure 12. Packet delivery ratio under different number of nodes.

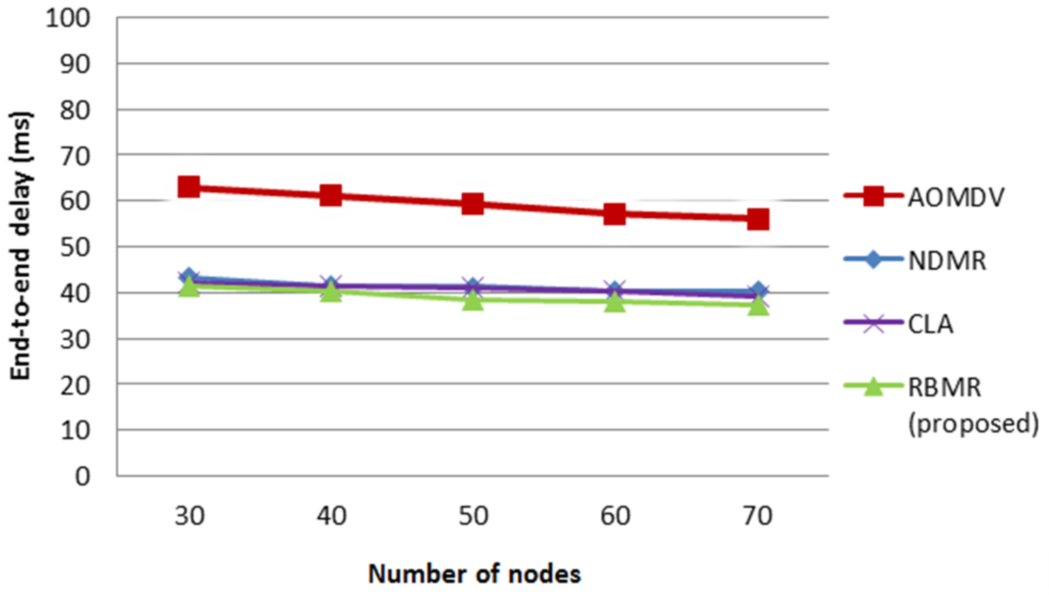

Figure 13. End-to-end delay under different number of nodes.

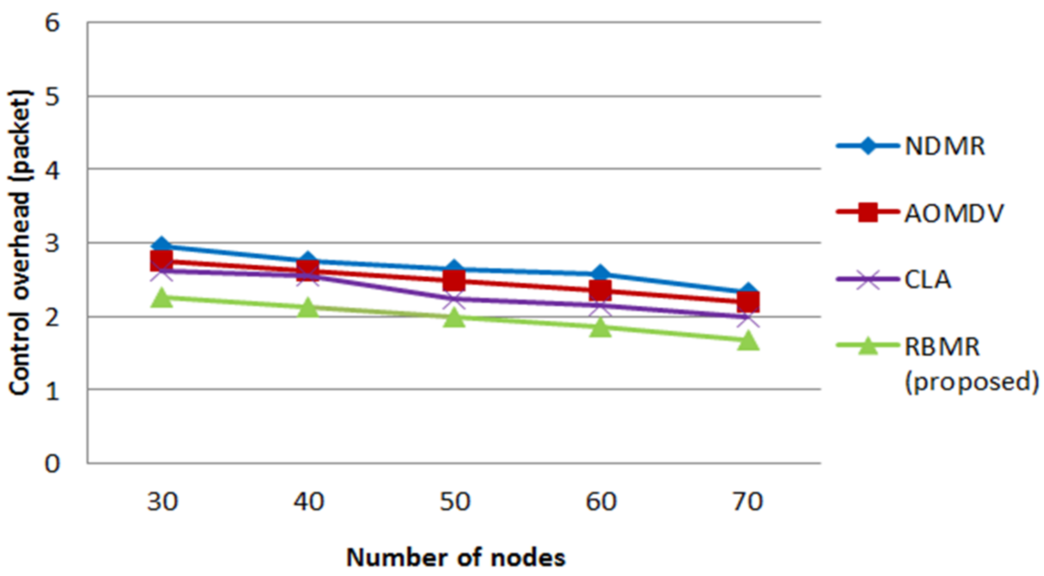

Figure 14. Control overhead under different number of nodes.

Chapter 6

Conclusion and Future Work

6.1 Concluding remarks

In this paper, we have presented a novel and efficient road-based multipath routing protocol for urban VANETs. We establish and maintain two node-disjoint paths and begin data forwarding once the first route (path) is established. The second route is a backup route. The vehicle persistence score (VPS) is used to select a stable neighbor as a relay node to forward packets. The proposed RBMR enhanced the packet delivery ratio by 9%, 6%, and 15%, end-to-end delay by 28%, 11%, and 7%, and control overhead by 30%, 25%, and 19% compared with AOMDV, NDMR, and CLA, respectively. Simulation results support that the proposed RBMR performs well in urban VANET environments and is better than two existing node-centric multipath routing protocols and one road-based single path routing protocol.

6.2 Future work

In future work, we may establish more than two node-disjoint paths and use the two most reliable paths to transfer packets. In addition, we may combine multimedia streaming with the proposed RBMR to provide more efficient multimedia streaming for urban VANETs.

Bibliography

[1] S. Lee and M. Gerla, "Split multipath routing with maximally disjoint paths in ad hoc networks," in *Proc. IEEE International Conference on Communications*, pp. 3201-3205, Sept. 2001.

[2] Y. Yuan, H. Chen, and M. Jia, "An optimized ad-hoc on-demand multipath distance vector (AOMDV) routing protocol," in *Proc. IEEE Asia-Pacific Conference on Communications*, pp. 569-573, Aug. 2005.

[3] M. Abolhasan, T. Wysocki, and E. Dutkiewicz, "A review of routing protocols for mobile ad hoc networks," in *Proc. IEEE Asia-Pacific Conference on Communications*, pp. 600-604, Aug. 2003.

[4] J. Nzouonta, N. Rajgure, and G. Wang, "VANET routing on city roads using real-time vehicular traffic information," *IEEE Transactions on Vehicular Technology*, vol. 58, pp. 3609-3626, Sept. 2009.

[5] B. Karp and H. T. Kung, "GPSR: Greedy perimeter stateless routing for wireless networks," in *Proc. IEEE International Conference on Mobile Computing and Networking*, pp. 243-254, Jan. 2000.

[6] C. Ahn and S. Chung, "A node-disjoint multipath routing protocol based on AODV in mobile ad hoc networks," in *Proc. IEEE International Conference on Information Technology*, pp. 828-833, Apr. 2010.

[7] Y. H. Ho, A. H. Ho, and K. A. Hua, "Routing protocols for inter-vehicular networks: a comparative study in high-mobility and large obstacles environments," *Computer Communications Journal - Special Issue on Mobility Protocols for ITS/VANET*, vol. 31, pp. 2767-2780, Nov. 2008.

[8] X. Li and C. Li, ”On-demand node-disjoint multipath routing in wireless ad hoc networks,” in *Proc. IEEE International Conference on Local Computer Networks*, pp. 419-420, Apr. 2004.

[9] B. Xue, P. Ren, and S. Yan, “Link optimization ad-hoc on-demand multipath distance vector routing for mobile ad-hoc networks,” in *Proc. International Conference on Wireless Communications, Networking and Mobile Computing*, pp. 1-6, Sept. 2009.

[10] K. Marina and R. Sami, ”On-demand multipath distance vector routing in ad hoc networks,” in *Proc. 9th International Conference on Network Protocols*, pp. 14-23, Sept. 2001.

[11] X. Huang and Y. Fang, “Performance study of node-disjoint multipath routing in vehicular ad hoc networks,” *IEEE Transactions on Vehicular Technology*, vol. 58, pp. 1942-1950, May 2009.

[12] M.-H. Wei, K.C. Wang, and Y.-L. Hsieh, ”A reliable routing scheme based on vehicle moving similarity for VANETs,” in *Proc. IEEE Region 10 Conference (TENCON)*, pp. 426-430, Nov. 2011.

[13] H.-F. Ho, K.C. Wang, and Y.-L. Hsieh, “Resilient video streaming for urban VANETs,” in *Proc. 7th Workshop on Wireless Ad Hoc and Sensor Networks*, Aug. 2011.

[14] “The network simulator (NS2),” [Online]. Available: http://www.isi.edu/nsnam/ns/.

[15] M. Fiore, J. Härri, F. Filali, and C. Bonnet, “Vehicular mobility simulation for VANETs,” in *Proc. 40th Annual Simulation Symp.*, pp. 301-309, Mar. 2007.

[16] “IEEE 802.11p-Wiki,” [Online]. Available: http://en.wikipedia.org/wiki/IEEE_802.11p.